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Determining potential for cavitation in stepped channels

Laboratory tests show that new spillway designs can call for higher specific discharge without risking cavitation damage.

What Is The Problem?

Stepped channels have been used for centuries as efficient and effective ways to dissipate energy in spillways and other water channels. In the late 1980s, dam construction began featuring roller-compacted concrete, which has a stepped lift process, producing stairstep-shaped dams. This technique spurred designers to choose stepped channels for spillways. Stepped spillway designs can have high hydraulic heads, resulting in high-velocity flows on the spillway. These high flows make the potential for cavitation a major design consideration.

When water is subjected to localized pressure reductions below the vapor pressure of water, vapor bubbles or cavities can form. As the vapor cavities travel with the flow and the local pressure conditions rise, these cavities implode. Repeated implosions near a solid boundary, such as the spillway surface, can erode the surface materials. Researchers have studied many topics associated with stepped channels, including air entrainment, velocity and pressure distributions, and energy dissipation. Still, the uncertainty on whether cavitation damage would be possible on stepped spillways has resulted in recommending limited specific discharges (discharge per unit width) and using aeration slots or ramps to reduce cavitation. These design limits can significantly increase the width of the spillway structure, resulting in higher construction costs.

However, new spillway designs have stretched these recommended limits particularly on discharge capacity. We need to understand how cavitation forms on stepped spillways to determine if these large discharges may result in conditions that risk cavitation damage.

What Is The Solution?

We conducted tests at Reclamation's Denver laboratory to investigate the cavitation potential of a novel stepped spillway designed for the Joint Federal Project (JFP) at Folsom Dam, California. While no existing stepped spillway installations have reported cavitation damage, the design parameters for the JFP spillway call for specific discharges much higher than any stepped spillway currently in service.

These tests were performed in our low ambient pressure chamber where ambient pressures are lowered close to the vapor pressure of water, allowing local pressures to drop below the vapor pressure at much reduced water velocities. This allows us to visualize cavitation in a controlled setting to predict what will occur under normal operating conditions.

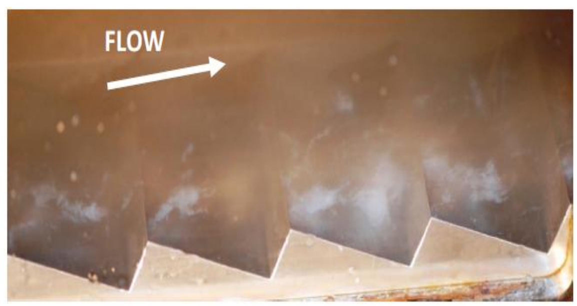
The test program revealed a good correlation between the critical cavitation condition and the roughness of the stepped configurations that we tested. A range of slopes were investigated, and actual damage in non-aerated flow conditions was verified and found to be slope-dependant. Thus, stepped spillway designs can pose risks for cavitation damage, especially on spillways of slopes less than 1 to 1. Thus, this risk needs to be considered in the spillway design.

Who Can Benefit?

Designers of new spillways can now use these results to determine safe operating limits for their stepped spillways.

Where Have We Applied This Solution?

We used these tests originally for the JFP spillway. However, the test program showed good potential to provide generalized data for stepped spillways, and Reclamation's Dam Safety Office and Science and Technology Programs have provided additional funds to extend the analysis to a broader range of designs.



Cavitation appearing on a steep sloped stepped spillway.

Future Development Plans

We plan on refining our study to focus on damage from cavitation on stepped spillway designs. We found that there was a difference in damage based on slope—even with similar levels of cavitation. While we now know the potential for cavitation, and that damage can occur (particularly at mild slopes), we need to systematically investigate the conditions where the onset of damage occurs, as this is generally well beyond the conditions where cavitation first forms.

More Information

Publications are forthcoming.

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